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The Economic Complexity of the Visegrád Countries and the Role of Trade with Germany

Abstract

The contemporary division of production in the global economy poses challenges typical for dependent market economies of the Visegrád countries (V4: Czechia, Hungary, Poland, and Slovakia). This comparative study explores whether the foreign trade of V4 with Germany contributes to their structural change. The analysis seeks to determine the long-term impact of specific intra-industry trade variables on the economic complexity, examined at different levels of technological sophistication. Our findings show that as a result of the characteristics of the trade dynamics, the progress of V4 structural change remains not as comprehensive as expected. As a result, it is critically important to provide incentives aimed at strengthening the geographical diversification of their exports and upgrade their position within the global value chains.

Keywords

economic complexity | international trade | economic transition | structural change | Central Europe | Visegrád countries

JEL Codes

F14, F43, O11, O14, O57

1. Introduction

Over 30 years after the collapse of the Soviet bloc, which created a historic window of opportunity for strategic political re-orientation and economic transformation, the Visegrád countries (V4: Czechia, Hungary, Poland, and Slovakia) still find themselves with a variety of structural challenges to their growth and development. They have attained a level of income status in the upper-middle range and a semi-peripheral position both in the global market and in the intra-European division of labour and production, which is typical of dependent market economies (Nölke & Vliegenthart, 2009). However, the concepts behind the set of previous policies for growth and development suggest they may not have been fully adequate.

In this context, the notion of economic complexity has become a pivotal issue for emerging and transitioning economies, including the V4. It offers promising insights, provides a better understanding of their semi-peripheral position, and describes prospects for how structural transformation can begin to take shape. Structural transformation is defined as the process through which countries adapt and change what they produce and how they produce it on a structural level. This process involves a shift away from low-productivity output and low-wage employment structures into high-productivity and high-wage activities, which often entail a measure of upgrading and diversifying in the production and export baskets (cf. Felipe, Kumar & Abdon, 2014, p. 489; UNCTAD, 2016, p. 4; Basile, Parteka & Pittiglio, 2017; Cieślik & Parteka, 2021). This concept emphasizes that the types of products being exported are highly significant ('what you export matters') and, therefore, the process seeks to advance the economy from existing capabilities towards a more comprehensive transformation with high levels of specialization in goods with higher productivity (Hausmann, Hwang & Rodrik, 2007, p. 9). In other words, there is a transition from a resource-based and agricultural-based production structure towards a more sophisticated and technological one (Lapatinas, 2016, p. 1442).

For that reason, our research draws from scholarly thought of the international political economy (IPE) of development, global production, and order (cf. Gilpin, 2001; Ravenhill, 2008). It encourages critical exploration and investigation of the historical trade patterns and trajectories. At the same time, we recognise and reflect on the impact of the economic dynamics that exist between the V4 countries and Germany. Thus, a major focus of our research examines whether the trade relations between the V4 countries and Germany, their largest trading partner (Trade Map, 2021), have positively affected their economic complexity. In this way, the study aims to verify the supposition that trade ties are a key driving force towards economic modernisation (Balcer, Blusz & Schmieg, 2017, p. 17), bearing in mind that simple interconnectedness does not necessarily spark increases in productivity or local innovation (Canuto, 2021, p. 161). Thus, the demand to bring a level of economic convergence between the V4 countries and developed Western economies remains an earnest but implausible sequence of mid-term events.

The study primarily sets out to explore the intra-industry trade (IIT) of each country—Czechia, Hungary, Poland, and Slovakia—with Germany by focusing first on low-tech, mid-tech, and high-tech product clusters assuming that the positive impact of new technologies is more likely to induce structural change (Fagerberg, 2000; Romalis 2004; Debaere 2005). In the second step, our examination is conducted for products classified under the category of high-quality vertical trade. For each of them, a set of control variables have been added.

To the best of our knowledge, there have not been in-depth studies covering the economic complexity of the V4 countries. With that said, the findings and insights of this study can fill an important gap in the existing literature. Through an integrative approach, it can offer solid support for evidence-based public policies that are oriented towards structural transformation. From a comparative perspective, our results may also provide invaluable practical implications about the outcomes and consequences of this type of transition process that could enhance the effectiveness of policymaking in developing countries. Hence, we position our study as of the complementary nature to the growing research about the impact of global value chains (GVCs) on Central European economies.

The remainder of our article is structured as follows. The next section contains a brief review of the relevant literature on structural change with a focus on Central Europe. Section three outlines our methodological approach based on the concept of economic complexity. Next, in section four, we develop and expound on the technical aspects of our research. In section five, the results and findings of the analysis are brought forward and discussed. Finally, the study integrates these findings and concludes with a discussion of some policy implications and recommendations.

2. Literature Review on Structural Transformation in Central Europe

Overall, the academic comparative literature on structural transformation and change in Central Europe remains surprisingly scarce, whereas studies covering particular countries are quite well developed. While reviewing scholarly works in this section, we aim to position our research in the former strand, finding it much more insightful. At the same time, we also seek to shed light on an economic meta-narrative that includes some stylized facts and a flow of constructive ideas within the IPE that have stimulated our thinking recently and motivated much of this research.

V4 economies are trapped in "Globalisation's Missing Middle". They have not found a niche in the world market due to their inability to compete in high-value-added markets dominated by wealthy economies, insufficient skills, unsophisticated legal systems, and too high wages, making them also bound to lose the battle with China (Garrett, 2004, p. 89). As they moved towards an industrial structure based on a market economy, the countries were expected to experience some downsizing in industry (Raiser, Schaffer & Schuchhardt, 2004). The projected timeframe for the Czech, Hungarian, and Polish economies to eventually catch up with the EU-15 was estimated to be about 20 years or longer (Brüggemann & Trenkler, 2007; Kołodko, 2010). Unfortunately, these projections were short-sighted, and many questions remain.

Furthermore, as Drahokoupil (2008, p. 175) suggests, the states in the region converged towards distinctive models of the competition state, with their dominant strategies aimed at promoting competitiveness by attracting foreign direct investment (FDI). By fulfilling these expectations, foreign investors would play a crucial role in their transition. This openness, however, contributed poorly to the emergence of competitive indigenous firms (Rugraff, 2008), while on the other hand, FDI began to serve as a convergence vehicle, bringing about regional disparities in Central and Eastern Europe (Chapman & Meliciani, 2018). Against this background, Pavlínek, Domański, and Guzik (2009, pp. 43–44) insightfully identify Central Europe as being a part of a system of integrated peripheral markets, that are concentrated on the most cost-sensitive and labour-intensive parts of the production chain. As a result, foreign technological guidance directly resulting from the FDI inflow may have limited the space for public policymaking aimed at structural change.

Within this context, it became necessary to re-think industrialisation strategies and initiate thorough research on economic complexity and the existing capabilities in each country as key determiners for structural upgrading and future growth. This began to spark a lively debate about a new framework for development, smart industrial policy, and premature deindustrialisation (Lin, 2012; Wade, 2012; Vivarelli, 2014; Rodrik, 2016). Once effective, this would have resulted in an improved position of the V4 economies in the GVCs. By the same token, this framework stresses a central message that high productivity growth rates have been achieved in countries that were able to shift production from traditional to modern activities and to develop relatively complex export goods (Nübler, 2014, p. 117).

In that regard, research on German-V4 economic relations, together with their GVCs and core–semi-peripheral dimensions (Grodzicki & Geodecki, 2016; Bohle, 2018) tends to concentrate on potential technological spillovers. However, as Yeon, Lee & Baek (2021) suggest, the capability for technological development in the modern economy is not exogenous or self-sustaining, but rather the outcome of deliberate efforts for technological search and learning on the global market. Having additional or multiple sources of knowledge, skills, and embedded capabilities is where economic complexity begins to take effect. In other words, this expands prospects for gradual technological improvements in industrial goods, preservation of competitive advantages, and acquisition of new ones. Thus, high diversification of exports and low ubiquity make it difficult to imitate or compete with (Zhu & Li, 2017, p. 3826). Therefore, these components of high economic complexity are essential for driving economic growth and development (Felipe et al., 2012; Özgüzer & Oğuş-Binatlı, 2016), and they are one of the important determinants of the inflow of FDI, which itself indirectly expands the creation of human capital (Sadeghi et al., 2020).

3. Research Design and Methodology

3.1. Theoretical Foundations of the Empirical Model

The concept of economic complexity by Hidalgo and Hausmann (2009) stems from Adam Smith's ideas of the division of labour and specialisation. The larger the market, the easier it is to specialise and reinforce efficiency. With that said, despite the fact that economic complexity is formed through individual activities, it brings about economic development and general welfare. Based on this, Hidalgo and Hausmann (2009) inquired about the plausible reasons for differences in income *per capita* among various countries within a global context of cooperation and competition. Their investigation focuses on the concept of capabilities that are embodied in the tacit knowledge of diverse individuals and are manifested with certain combinations of quality and productivity levels (Felipe, Kumar & Abdon, 2014, p. 491). These are capabilities that cannot be outsourced elsewhere, such as infrastructure, regulatory framework, etc., and that are indispensable for economic performance. Hence, the deficiencies in economic complexity can influence and shape diverging levels of income (Hidalgo & Hausmann, 2009, pp. 15–16). Balland et al. (2022) state that productive knowledge underlying of economic complexity occurs in three types: embodied knowledge in tools, codified knowledge in tools, and finally tacit knowledge or know-how in brains. The level of know-how owned by individuals has certain limitations. That is why its increase in a society is constrained by division of tacit knowledge among individuals and depends on the Smith's idea of specialisation, i.e., first individuals specialise, then selected firms provide more sophisticated output, and

Table 1. Variables, definitions, data sources, and summary statistics

Variables	Definition	Data Source	Num. of Observation	Mean	Std. Dev.
ECI	Economic complexity index	Harvard MIT (2022)	76	1.2642	0.2606
GL_HT	GL-index with Germany for high-tech product clusters	Authors' calculations based on Trade Map (2021)	76	0.3097	0.0953
GL_MT	GL-index with Germany for mid-tech product clusters	as above	76	0.4728	0.0959
GL_LT	GL-index with Germany for low-tech product clusters	as above	76	0.4364	0.0609
VERTHQ_HT	Vertical trade/high quality with Germany for high-tech product clusters	as above	76	0.1180	0.0544
VERTHQ_MT	Vertical trade/high quality with Germany for mid-tech product clusters	as above	76	0.1655	0.0458
VERTHQ_LT	Vertical trade/high quality with Germany for low-tech product clusters	as above	76	0.1131	0.0302
Fdi	Foreign direct investment, net inflows (% of GDP)	World Bank	76	5.9880	12.9742
LogImport	Logarithm of share of intermediate and capital goods imports in total imports from Germany	Authors' calculations based on UN Comtrade (2022)	76	1.9255	0.0195
LogRD	Logarithm of gross domestic spending on R&D (% of GDP)	OECD	76	-0.0234	0.1756
LogResearcher	Logarithm of researchers per 1000 employed	as above	76	0.7239	0.1103

Source: Authors' own calculations

finally countries become more diversified. Hence, societies comprising highly specialised individuals have more diversified knowledge, and finally they become able to transform their economic structures (cf. Balland et al., 2022, p. 2).

At this juncture, it is important to highlight the relations between knowledge and network interactions. While fitting into the economic complexity approach, the level of embedded knowledge in a society does not depend on the aggregate level of individual knowledge. It rather depends on its diversity and exchange capabilities within a heterogeneous network of consistent interactions, so the total value is more than the sum of its individual parts. Thus, it is also vitally important to notice a distinction between modern and traditional societies. The most significant characteristic of modern societies in this context is that they have substantial capabilities to use their extensive and fragmented knowledge collectively. This becomes a reality via certain interaction channels between the individual members of a society functioning as a social network (Hausmann et al., 2011, p. 15).

Also, the variety and diversity of current production has a profound impact on future capabilities, as innovations and product upgrades are key for countries to become more effective through novel combinations of knowledge and expertise. This process, in turn, enhances prospects for faster and innovation-driven economic development. Therefore, products that provide equal income but have distinct complexity levels will not provide equal developmental opportunities (Hidalgo, 2009, 3). Furthermore, in this context, it becomes clear how economic complexity intertwines with general welfare in that economic complexity is a driving force rather than a symptom of it (Hausmann et al., 2011, p. 27). Change in the economic complexity level is related to structural transformation of economies since productive resources are moved from low-complex to high-complex activities

(Adam et al., 2021; Sørensen et al., 2020, p. 1). This is why we decided to use the economic complexity index (ECI) to capture the structural change in V4 countries.

The empirical model used in the present study examined the effect of economic relations with Germany on the structural transformation of V4 countries, which is represented by the economic complexity level. In Table 1, we explain the set of variables in Models 1 and 2. The analysis covers the period from 2001 to 2019. Each variable has 76 observations, thus with no loss we have a balanced panel data at our disposal. Moreover, a low value of the standard deviation indicates a modest level of instability in the variables.

Based on this, the following models are used to examine the effect of trade with Germany on V4 countries' economic complexities.

$$ECI_{it} = \beta_{0t} + \beta_1 GL\_HT_{it} + \beta_2 GL\_MT_{it} + \beta_3 GL\_LT_{it}$$
$$+ \beta_4 Fdi_{it} + \beta_5 LogImport_{it} + \beta_6 LogRD_{it}$$
$$+ \beta_7 LogResearcher_{it} + \varepsilon_{it} \qquad (\boldsymbol{Model\ 1})$$

$$ECI_{it} = \beta_{0t} + \beta_1 VERTHQ\_HT_{it} + \beta_2 VERTHQ\_MT_{it}$$
$$+ \beta_3 VERTHQ\_LT_{it} + \beta_4 Fdi_{it} + \beta_5 LogImport_{it}$$
$$+ \beta_6 LogResearcher_{it} + \varepsilon_{it} \qquad (\boldsymbol{Model\ 2})$$

The point of departure for Hausmann et al. (2011, p. 24) in their calculations of economic complexity index is the M_{cp} matrix where the elements are 1 if 'country c' produces 'product p', and 0 if it does not. 'Diversity' $(k_{c,0})=\Sigma_p M_{cp})$ and 'Ubiquity' $(k_{p,0})=\Sigma_c M_{cp})$ values are obtained by summing up the rows and columns of the M_{cp} matrix. Thus, the higher the diversity, the more products the country produce. Similarly, the higher the ubiquity, the more countries are producing the product.

Hausmann et al. (2011) propose new measurements by using reciprocal information carried by the diversity and ubiquity values to obtain reliable results about the number of capabilities that exist or are required for more sophisticated production. As a result, the economic complexity index (ECI) is formulated as follows:

$$ECI = \frac{\vec{K} - < \vec{K} >}{stderror(\vec{K})} \qquad (1)$$

In Equation (1), $\vec{K}$ corresponds to the eigenvector that relates to the second-highest eigenvalue of the $\widetilde{M}_{cc'}$ matrix while $< \vec{K} >$ represents the average. Hidalgo and Hausmann (2009, p. 10575) empirically tested the relations between ECI and macroeconomic indicators and were able to infer the substantiality of the economic complexity levels. As a result, the ECI (i) provides information on the current level of knowledge and the current set of capabilities, (ii) has a high correlation with the level of income *per capita*, (iii) provides a good estimate on future growth and performance, and (iv) determines the complexity level of future exports.

Our Model 1 takes a broader perspective of the overall IIT impact on the evolution of V4's ECI. The intensity of IIT is measured by the Grubel-Lloyd (GL) index at the six-digit disaggregation level of the harmonized system (HS). The way we classify product clusters according to their technological intensity (primary products, resource- and labour-intensive products, low-tech, mid-tech, and high-tech goods) adheres to the approach of the United Nations Conference on Trade and Development (UNCTAD, 2012).

In Model 2, for the sake of greater precision, we narrow our analysis to exported goods of higher quality that may be of particular importance for a positive change of the V4's ECI. Therefore, applying the method of Greenaway, Hine, and Milner (1994; 1995) and Caetano and Galego (2007), we extract three IIT subcategories: horizontal trade (HORT, countries A and B trade with substitute goods of the same quality); low-quality vertical trade (VERTLQ, country A exports substitute goods of lower quality while country B does the opposite); and high-quality vertical trade (VERTHQ, country A exports substitute goods of higher quality while country B does the opposite). Their unit values approximate the quality of a given commodity: HORT occurs when the difference between the average unit value of exported and imported goods does not exceed more than ± 15%, whereas vertical trade (VERTLQ and VERTHQ) occurs when the proportion of the average unit values is below or above 15%.

Moreover, the extent of simultaneous exports and imports for differentiated products that are close substitutes illustrates the extent of structural transformations and export diversification (Cadot, Carrere & Strauss-Kahn, 2011). Put differently, the growing intensity of IIT implies that factor endowment and internal capabilities essential for technologically advanced and thus sophisticated/complex goods are improving. They are enablers of quality-driven, supply-side differentiation of goods within industries defined by the range of outputs obtainable from a particular type of capital as well as by effects typical of the learning curve (reduction of average costs, practical experience, enhanced calibration of value-creating processes). With goods being traded internationally, preferably with developed countries representing overlapping demands, they tend to form streams of vertical trade (Falvey, 1981), i.e., of significantly diversified physical characteristics and varying prices, while the horizontal component is being put down to taste-induced consumers' love of variety (Krugman, 1979, 1980) when goods differ barely, and their prices are somewhat equivalent (± 15%; see above). With that said, more intense market competition with differentiated products, especially of high quality, brings about additional pressures on domestic producers. These, in turn, contribute to regular improvements in vital capabilities, productivity, indigenous innovative potential, and research and development activities in particular.

Additionally, our core independent variables were supplemented with some control variables that are examined in the empirical literature to have an effect on structural change. The Fdi variable is meant as a proxy to measure the technological spillover effect of FDI inflow as it is believed to be a channel of acquiring and transferring technology (Sepehrdoust, Davarikish & Setarehie, 2019). Theoretically, we expect it to have a positive sign since, as mentioned by Balland et al. (2022), the transfer of new knowledge is supposed to accelerate technological spillovers and contribute to structural transformation. However, we also keep in mind that the FDIs' effects in terms of technological spillovers remain debatable, in particular as far as upgrading at the micro-level is concerned (Javorcik, Lo Turco & Maggioni, 2018). The LogImport variable represents the share of intermediate and capital goods imports in total imports from Germany. As claimed by Sepehrdoust, Davarikish, and Setarehie (2019), innovations are not brought about only by domestic R&D activities, but also by those of other countries that might be transferred via import of intermediate and capital goods. Its sign may change depending on the value added created by V4 countries. If these countries use intermediate and capital goods imports not only to assemble, but also to create a new value, then the sign may be positive. Finally, LogRD and LogResearcher variables are added because they represent the effect of know-how creation (cf. Neagu, Neagu & Gavurova, 2022) and human capital qualities on the ECI (cf. Yalta & Yalta, 2021). Their signs are expected to be positive, too.

3.2. Econometric Methodology

To examine the effect of economic interaction with Germany on the structural change of V4 economies, our procedure draws from Feige and Swamy (1974), as well as Boness and Frankfurter (1977). First, the stationarity of the variables was tested by implementing CIPS and IPS tests. Second, we checked homogeneity of slope coefficients to prove it heterogeneous. Finally, based on these results, the Swamy's random coefficient model estimator was applied to the stationary variables.

3.2.1. Panel Unit Root Tests

The stationarity of the variables in the econometric analysis remains crucial for obtaining reliable results; otherwise, it may cause spurious regression. To check the stationarity, the first- and second-generation unit root tests are applied. The former tests for the nonexistence of cross-section dependence, while the latter tests whether a cross-section dependence exists (Brooks, 2014, p. 547). In order to test the stationarity of the series, the appropriate unit-root test is chosen according to the results of the analysis for cross-section dependence. In the present study, the cross-section dependency test was applied to all variables, and the results are presented in Appendix A. Based on these results, the IPS (first generation unit root test) and CIPS (second generation unit root test) tests were intended. For the IPS test, we applied the unit-root procedure for each cross-section unit separately, so its statistical results were obtained by taking the average of the ADF test statistic for each of the cross-section units. The model in Equation (2) is used for the IPS unit root test, where $t=1,2,\ldots,N$ and $t=1,2,\ldots,T$, with N in this case referring to the cross-section number and T to the time dimension (Barreira & Rodrigues, 2005, p. 5):

$$\Delta Y_{it} = \rho_i Y_{it-1} + \sum_{L=1}^{Pi} \Phi_{iL} Y_{it-L} + \mu'_i \gamma + u_{it} \tag{2}$$

The null hypothesis (H_0) refers to the nonstationarity of any cross-section unit, while the alternative hypothesis (H_1) refers to the stationarity of at least one cross-section unit. The IPS test statistic is represented in Equation (3), by taking $t_{\rho i}$ as the individual test statistic:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{\rho i} \tag{3}$$

CADF test is applied in case of both $T > N$ and $N > T$. Monte Carlo simulations based on various models indicated that CADF test reveals robust results for small T and N values by using the following equation (Pesaran, 2007):

$$y_{it} = (1 - \emptyset_i)\mu_i + \emptyset_i y_{i,t-1} + u_{it},$$
$$i = 1, \ldots, N; \quad t = 1, \ldots, T \tag{4}$$

It is assumed in Equation (4) that y_{it} is generated by depending on the dynamic linear heterogeneous panel data model. The null hypothesis in the CADF test states that all cross-section units have a unit root, while the alternative hypothesis states stationarity. The CADF test gives test statistics for each cross-section unit. Then, CIPS statistics are obtained by taking the average of all these test statistics that belong to cross-section units (Pesaran, 2007):

$$CIPS = N^{-1}\sum_{i=1}^{N} CADF_i \tag{5}$$

3.2.2. Swamy's Random Coefficient Panel Regression Estimator

As an alternative to fixed coefficient models in panel data analysis, there are also random coefficient models that apply stochastic specifications for each cross-section unit. These models allow coefficient vectors to differ among cross-section units (Hsiao & Pesaran, 2004, p. 3). Following Swamy, the random coefficient model is written in matrix notation as follows (Poi, 2003, p. 32):

$$y_i = X_i\beta_i + \epsilon_i \tag{6}$$

In equation (6), β_i is a k x 1-dimensional parameter vector that is related to a β common parameter vector and specific to the i cross-section unit (Poi, 2003, p. 302): $\beta_i=\beta+\upsilon_i$. Swamy (1970) stated that it is required to test before estimation whether β_i parameter vectors are fixed and homogeneous among cross-section units. The null hypothesis of the homogeneity test (also called the parameter constancy test) refers to homogeneity (Swamy, 1970, p. 319):

H'_0: $\beta_1=\beta_2=\cdots=\beta_n=\beta$.

In the case of rejecting the null hypothesis, the heterogeneity of parameter vectors is accepted, and it is not correct to pool the data and estimate a unique parameter vector representing the relation between variables (Swamy, 1970, p. 319).

4. Results and Discussion

As already mentioned, we take the intensity of IIT with Germany as an indicator of structural change that can lead to development in the quality, sophistication, and complexity of a country's exports. Our study examines low, mid, and high-tech product clusters, comprising 3087 categories at the six-digit level of disaggregation of the trade data (see Figures 1, 2, and 3). We found that the values of the GL index developed along the same pattern for the first two categories: the Czech values were high and durable, while those of all others improved, with Poland making the most substantial progress. This may prove that V4 exporters of less technologically advanced goods still make use of their competitive edge as a cheaper and more productive supplier with respect to the German market. Considering the geographical proximity and flexible organisation of production within the GVCs, there are major cost advantages for the much more globally oriented German exporters. Hence, it can reinforce the competitive division of labour among V4 economies, especially in terms of motor vehicle supplies, parts, and accessories, just to name a few. This will inevitably result in major challenges of industrial upgrading and attempts to mitigate the trap of foreign technological guidance.

Regarding the high-tech product cluster, the intensities of IIT increased only with Poland and Czechia. Their companies exporting to Germany may have benefited from technological and knowledge spillovers, whereas we found no considerable transformations for Hungary and Slovakia. These types of developments create an opportunity for comprehensive learning by doing. From this

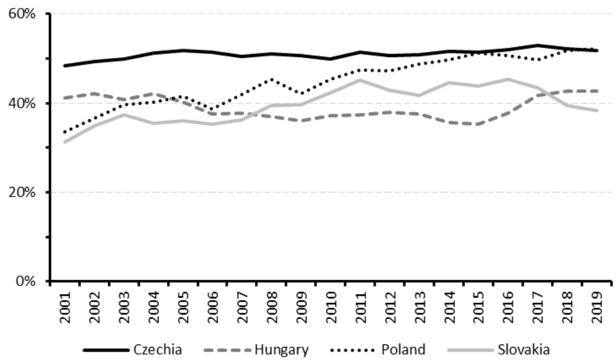

Figure 1. The GL-index of V4 countries in trade with Germany in low-tech goods (2001–2019).
Source: Authors' own calculations based on Trade Map (2021).

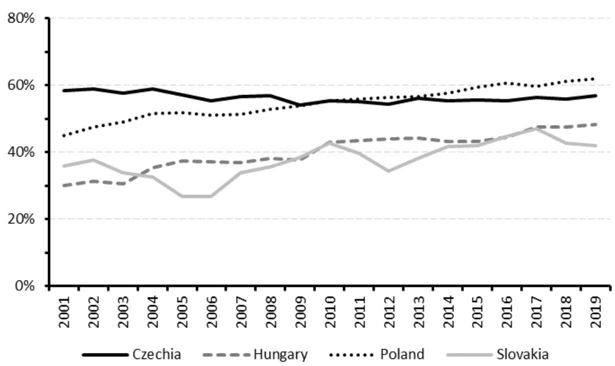

Figure 2. The GL index of V4 countries in trade with Germany in mid-tech goods (2001–2019).
Source: Authors' own calculations based on Trade Map (2021).

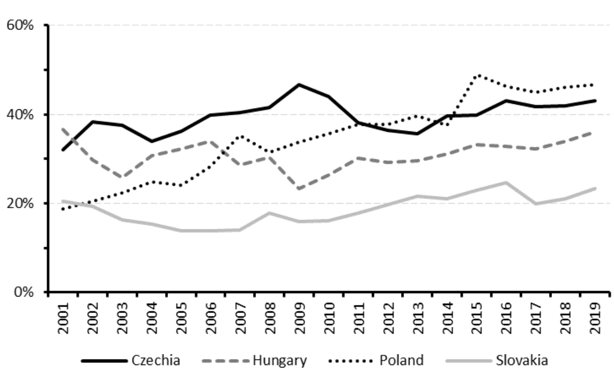

Figure 3. The GL index of V4 countries in trade with Germany in high-tech goods (2001–2019)
Source: Authors' own calculations based on Trade Map (2021).

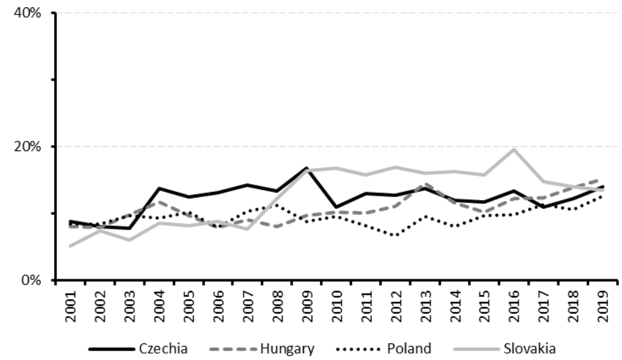

Figure 4. The GL-index of V4 countries in high-quality vertical trade with Germany in low-tech goods (2001–2019).
Source: Authors' own calculations based on Trade Map (2021).

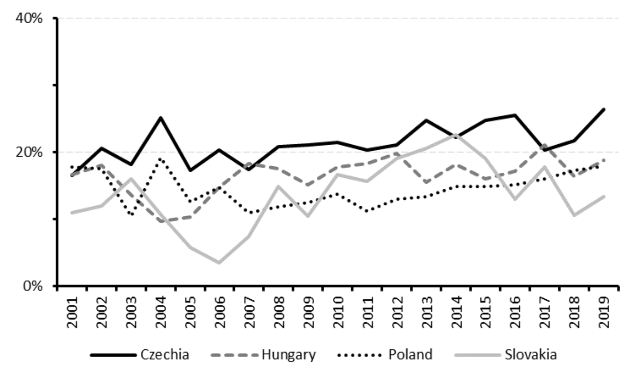

Figure 5. The GL-index of V4 countries in high-quality vertical trade with Germany in mid-tech goods (2001–2019).
Source: Authors' own calculations based on Trade Map (2021).

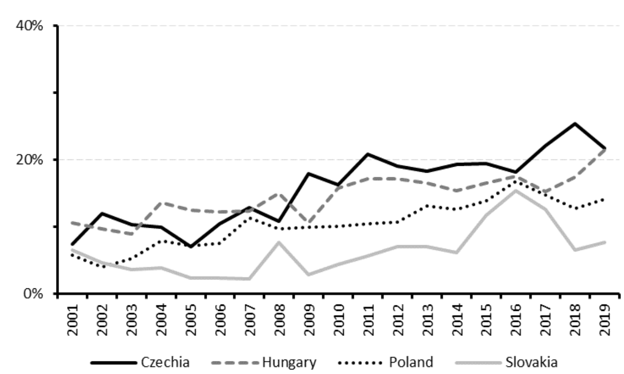

Figure 6. The GL index of V4 countries in high-quality vertical trade with Germany in high-tech goods (2001–2019).
Source: Authors' own calculations based on Trade Map (2021).

Table 2. Unit root test results

CADF Unit Root Test		
Variables	**CIPS Statistics**	
	Level	**1st difference**
ECI	-3.717***	-
GL_HT	-2.758*	-
GL_MT	-1.21	-3.724***
GL_LT	-1.30	-4.126***
LogImport	-2.886**	-
LogRD	-2.34	-4.113***
LogResearcher	-2.93**	-
VERTHQ_HT	-3.062**	-
Im-Pesaran-Shin Unit Root Test		
Variables	Intercept	Intercept - Trend
Fdi	-4.23201***	-4.08435***
VERTHQ_MT	-2.00021**	-2.20049**
VERTHQ_LT	-1.36331	-0.64119
Δ VERTHQ_LT	-8.86728***	-7.62207***

***, ** and * refer to 1%, 5% and 10% significant levels, respectively. The critical values for CADF test are -3.15 (1%), -2.88 (5%) and -2.74 (10%).

Table 3. Parameter constancy test results

Coefficient	**Model 2**	**Model 3**
χ^2	694.57	588.93
	(0.000)	(0.000)

The values in parentheses refer to *p*-values.

perspective, the strategic aim would be to enhance the business environment to maintain sustainable growth in high-tech domestic companies and their subsequent innovations.

Looking at the findings of VERTHQ in low-tech, mid-tech, and high-tech product clusters (see Figures 4, 5, and 6), which is often seen as the most valuable category, our results reveal that this particular subcategory of IIT was strengthened in all V4 economies. The most substantial transformations took place in Slovakia for low-tech products (in particular, for HS 7210: flat-rolled products of iron or non-alloy steel, of a width more than 600 mm, and HS 8301: padlocks and locks of base metal); in Czechia for mid-tech ones (in particular for HS 8708: parts and accessories for motor vehicles, HS 8413: pumps for fluids, liquid elevators, and parts thereof, and HS 8536: electrical apparatus for switching or protecting electrical circuits); and in Czechia, Hungary, and Poland for high-tech goods.

A closer investigation of trade data at the four-digit disaggregation level for high-tech goods reveals that certain product clusters are of particular importance in terms of their shares in total exports to Germany after 2010. They have sustained their high-quality advantages in the vertical trade subcategory:

- in Czechia: HS 8517 (telephone sets, including telephones for cellular networks or other wireless networks), and HS 3004 (medicaments consisting of mixed or unmixed products);
- in Hungary: HS 8529 (parts suitable for solely or principally with a transmission and reception apparatus), and HS 8518 (microphones and stands thereof, loudspeakers, headphones, and earphones, audio-frequency electric amplifiers, electric sound amplifier sets, parts thereof);
- in Poland: HS 3917 (plastic tubes, pipes, hoses, and fittings) and HS 8471 (automatic data-processing machines and units thereof);
- in Slovakia: HS 3004 (as above) and HS 3920 (plates, sheets, film, foil, and strip of noncellular plastics).

Having provided some descriptive characteristics of tendencies within the V4's IIT with Germany, we turn now to the econometric analysis of our panel data.

As explained in the methodological section, stationary variables need to be tested beforehand. Here, we applied Im-Pesaran-Shin unit root test to the variables VERTHQ_MT, VERTHQ_LT and Fdi with no cross-section dependence, while the other variables have to be examined via the CIPS test, because they involve cross-section dependence (see Appendix A). The unit root test results are presented in Table 2.

According to the CADF test results, ECI, GL_HT, LogImport, LogResearcher, and VERTHQ_HT variables are stationary at level, while GL_MT, GL_LT and LogRD variables becomes stationary at first difference. The Im-Pesaran-Shin test result indicates that Fdi and VERTHQ_MT variables are stationary at level, while VERTHQ_LT variable becomes stationary at first difference.

Based on the results in Table 2, we differentiated GL_MT, GL_LT, LogRD, and VERTHQ_LT variables before estimating regression. Moreover, testing

Table 4. Random coefficient regression model coefficients for Model 1

Country	Czechia		Hungary		Poland		Slovakia	
GL_HT	-0.0704	(0.404)	0.1050	(0.563)	1.2351***	(0.249)	1.289***	(0.5005)
GL_MT	0.2208	(0.579)	0.0689	(0.512)	-1.4072	(1.283)	-0.279	(0.241)
GL_LT	1.3453	(1.066)	1.7504*	(0.947)	0.1776	(0.794)	-0.511	(0.643)
FDI	-0.0087	(0.006)	0.0001	(0.0004)	0.0016	(0.0098)	0.009	(0.0064)
LogImport	-1.352*	(0.694)	-1.251*	(0.694)	-1.2075*	(0.698)	-2.827***	(0.673)
LogRD	0.6005	(0.454)	0.1768	(0.553)	1.228**	(0.533)	-0.109	(0.287)
LogResearcher	0.841***	(0.144)	1.1051***	(0.183)	-0.4478**	(0.215)	1.776***	(0.307)

***, ** and * refer to 1%, 5%, and 10% significant levels, respectively. The values in parentheses correspond to standard errors.

parameter constancy is also required; therefore, Swamy's homogeneity (parameter constancy) test results are presented in Table 3.

Based on the *p*-values in Table 3, we reject the null hypothesis that coefficient vectors are not homogeneous. In other words, coefficients differ from country to country. Thus, we cannot pool the data to estimate the coefficient.

Before estimation, we also clarify whether or not there is a multicollinearity problem for the models examined. In order to detect it, we examine bivariate correlations between explanatory variables and expect their absolute values to be lower than 0.80 to avoid multicollinearity. If the value is greater than the given threshold, multicollinearity generates a serious problem (Senaviratna & Cooray, 2019, p. 3).

Apart from examining bivariate correlations, the other way to detect multicollinearity between the explanatory variables is to calculate VIF values. Accordingly, if the VIF value of a variable is higher than 5.0, then this variable is highly correlated with other explanatory variables (Kim, 2019, p. 559). Thus, we calculated bivariate correlations (see Appendix B) and Variance Inflation Factor (VIF) values (see Appendix C). All of the bivariate correlations for Model 1 are lower than 0.80, which means that multicollinearity does not exist. The VIF values also justify this result. When checking the bivariate correlations for Model 2, we see that the LogRD variable has a 0.86 correlation with the VERTHQ_HT variable. Since the VERTHQ_HT variable is one of the core variables of the study, we exclude the LogRD variable from Model 2 to avoid multicollinearity. The VIF values for Model 2 also indicate that there is no multicollinearity.

Table 4 presents the Swamy estimations of Model 1. To some extent, the obtained results are in line with our theoretical assumptions. Surprisingly, bearing in mind the overall IIT intensity, neither the GL_HT, GL_MT, nor GL_LT are statistically significant for Czechia, while the GL_LT variable is the only one that is significant for Hungary, having a positive effect on the ECI. In the case of Poland and Slovakia, the GL_HT variable turns out to be significant, and its effect on the ECI is positive with a greater magnitude for Slovakia. As far as the Fdi variable is concerned, it has no significant effect on the ECI of V4 countries. This may imply that the activity of international businesses in Central Europe aimed at extracting advantages that are not related to technology and innovations. What all V4 countries have in common is the negative effect of the LogImport variable on economic complexity levels. This means that the participation of V4 economies in GVCs oriented towards the German industrial complex and performing highly defragmented production tasks does not trigger required direction of structural upgrading. Quite the contrary, the GVCs' configuration and the V4's position within may solidify and strengthen prevailing burdens caused by the technological gap.

Furthermore, the LogResearcher variable is significant in all countries and have a positive effect on the ECI, except Poland, while the LogRD variable remains significant only for Poland. Our results may demonstrate that V4 economies have already achieved a stage of economic development that depends more and more heavily on the top-quality human capital and innovation capabilities. Therefore, endogenous creation of knowledge and innovations remains a strategic necessity for these economies to complete their transition and to become more successful in catching up with technological advances.

Table 5. Random coefficient regression model coefficients for Model 2

	Czechia		Hungary		Poland		Slovakia	
VERTHQ_HT	1.195***	(0.331)	1.484**	(0.649)	2.543***	(0.599)	1.5311***	(0.280)
VERTHQ_MT	0.065	(0.4008)	0.356	(0.766)	-1.695**	(0.817)	-0.6512***	(0.218)
VERTHQ_LT	-0.256	(0.395)	-0.114	(1.149)	-1.993*	(1.153)	-0.819***	(0.312)
FDI	-0.002	(0.004)	0.000	(0.0009)	-0.004	(0.0125)	-0.006	(0.003)
LogImport	-0.9514**	(0.446)	-1.657***	(0.494)	-1.291***	(0.491)	-2.544***	(0.468)
LogResearcher	0.4097***	(0.135)	0.9209***	(0.313)	0.300	(0.327)	1.708***	(0.187)

***, **, and * refer to 1%, 5%, and 10% significant levels, respectively. The values in parentheses correspond to standard errors.

Swamy estimation results for Model 2 are presented in Table 5. Accordingly, the VERTHQ_HT variable is both significant as well as positive for every country, with its highest impact in Poland. When it comes to VERTHQ_MT and VERTHQ_LT variables, they are significantly negative in Poland and Slovakia. This may be interpreted by the fact that more and more low-cost manufacturers from developing countries have sufficient capabilities to produce top-quality goods making efficient use of aging technologies (mid-tech and low-tech). Therefore, it does not seem reasonable to exert predominant pressure on sustaining cost competitiveness. Yet again, the Fdi variable did not have a significant effect on the V4's ECI, while LogImport has a significantly negative effect for all of them. This result supports our observation given above of an ambiguous impact of GVC participation. When it comes to the LogResearcher variable, it has a significant and positive effect in the case of Czechia, Hungary, and Slovakia, highlighting the utmost importance of domestic intellectual capacity, creativity, and novel applications of knowledge.

6. Policy Implications and Concluding Remarks

The issues emerging from our findings gravitate specifically to the structural challenge of the technological gap. Recent developments of V4 economic complexity, and the intensities of their IIT with Germany, suggest that there might be some symptoms of productivity convergence and enhanced competitiveness. However, the impact of selected trade ties with the German economy is not as comprehensive as we would expect. An implication of this is the possibility that the inflow of foreign capital and the growing participation in GVCs may have been a factor in reinforcing the phenomenon of foreign technological guidance. That said, essential structural changes and adjustments within V4 economies could have been seriously impeded. Furthermore, higher intensities of IIT between V4 countries and Germany in low-tech and mid-tech goods, as compared with high-tech ones, still expose the reality of a technological gap and unequal competitive potentials. This may also explain our results.

These circumstances provide some novel clarification as to why the anticipated broad transfer of knowledge, skills, and capabilities might have become a matter of political wishful thinking. Nevertheless, this is what V4 economies need in order to consistently progress towards economic complexity and more technological sophistication. As long as the lion's share of V4 exports to Germany is comprises mechanical, electric, electronic, and automotive parts and accessories (HS 84, 85, and 87), there may be not enough political space and opportunities for a meaningful strategic response. This strategy would need to address, mitigate, and outweigh the risks of being caught somewhere in the middle of GVCs, as well as the risks of delocalization.

Within this framework, our major policy recommendation stresses the fundamental necessity for continuous diversification within the export markets and the particular goods being traded in those markets. The existing trade patterns, within which Germany stands at the core and the V4 countries are semi-peripheral, ought to be reconstructed, bearing in mind the potential impact of low-cost producers who strive continually for their share in GVC. Maintaining the status quo may bring about years of missed opportunities for economic development. Therefore, as V4 countries compete with the same or similar intermediate goods on the German market, which is deliberately sustained by the supply link patterns between Germany and Central Europe, the process should be finely balanced by a smart and evidence-based public policy of incentives for non-GVC-trapped domestic businesses.

Current progress such as an eagerness to export, higher national value-added content, and other relevant achievements must be reinforced, properly appreciated, and set as examples of best practice in ways that encourage others to follow these approaches. As Hausmann, Hwang, and Rodrik (2007, p. 24) express, the countries that are able to overcome externalities through policies that entice entrepreneurship into new activities can reap the benefits of higher economic growth. Thus, we see these types of successful and competitive domestic companies, which offer attractive jobs and effectively set a higher standard of what can be achieved, as incredibly important. Graduates at different levels of the education system can envision new possibilities, which then, in the long run, can serve as a vehicle that communicates more attractive career choices and strategies. This also aligns with observations made by Daude, Nagengast, and Perea (2016, p. 531) that policies facilitating the accumulation of the relevant human capital and facilitating integration into global value chains may be successful in strengthening export capabilities.

Finally, considering the characteristics of V4 trade with Germany and its impact on economic complexity, we posit that the strategic response for years to come should bring into the public spotlight the value and importance of structural upgrading, domestic production capabilities, and excellence within the national innovation systems. We can also presume that at the current stage of economic transition it is not advisable to continue to place an emphasis on attracting foreign capital primarily through low production costs and cheap labour. In our view, all these features would instead foster low-quality vertical IIT within which the dynamics of product differentiation are fuelled by basic factor and resource endowments. It is our conviction that this approach is misleading and may bring about additional developmental challenges for semi-peripheral economies. These challenges can lead to a petrification of the V4 economies' position within GVCs, and thus also to increased exposure to shocks in the global economy. Continued studies that take into account contexts and methods for speeding technological progress, creating innovation, encouraging global technological competition, understanding qualities of institutional framework, and developing strategic responses on how to gain unrestricted access to foreign sources of competitive advantages are therefore highly recommended.

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Compliance with Ethical Standards

On behalf of all authors, the corresponding author states that there is no conflict of interest. The authors declare that no funds, grants, or other support were received during the preparation of this manuscript. Our research did not involve human participants and/or animals.

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Appendices

Appendix A. Cross-section dependency test results

Variables	$CDLM_1$	$CDLM_2$	LM_{adj}
ECI	106.5706	27.87753	27.76642
	(0.000)	(0.000)	(0.000)
GL_HT	19.33611	2.695103	2.583992
	(0.003)	(0.007)	(0.009)
GL_MT	48.55743	11.13057	11.01946
	(0.000)	(0.000)	(0.000)
GL_LT	34.05162	6.943106	6.831995
	(0.000)	(0.000)	(0.000)
VERTHQ_HT	53.55607	12.57355	12.46244
	(0.000)	(0.000)	(0.000)
VERTHQ_MT	10.1532	0.044226	-0.066885
	(0.118)	(0.964)	(0.946)
VERTHQ_LT	14.61022	1.330855	1.219744
	(0.024)	(0.183)	(0.223)
Fdi	14.56701	1.318381	1.20727
	(0.024)	(0.187)	(0.227)
LogImport	30.15403	5.817966	5.706855
	(0.000)	(0.000)	(0.000)
LogRD	92.42095	23.79288	23.68177
	(0.000)	(0.000)	(0.000)
LogResearcher	67.20774	16.51445	16.40334
	(0.000)	(0.000)	(0.000)

Appendix B. Correlation Matrices for Model 1 and Model 2

Model 1

	GL_HT	GL_MT	GL_LT	Fdi	LogImport	LogRD	LogResearcher
GL_HT	1	-	-	-	-	-	-
GL_MT	0.7746	1	-	-	-	-	-
GL_LT	0.7667	0.7999	1	-	-	-	-
Fdi	0.0161	-0.1464	-0.1509	1	-	-	-
LogImport	-0.3492	-0.2576	-0.1261	-0.0871	1	-	-
LogRD	0.7107	0.4893	0.5864	-0.0058	-0.175	1	-
LogResearcher	0.0862	0.0952	0.2062	-0.1306	-0.0371	0.418	1

Model 2							
	VERTHQ_HT	**VERTHQ_MT**	**VERTHQ_LT**	**Fdi**	**LogImport**	**LogRD**	**LogResearcher**
VERTHQ_HT	1	-	-	-	-	-	-
VERTHQ_MT	0.5871	1	-	-	-	-	-
VERTHQ_LT	0.246	0.3713	1	-	-	-	-
Fdi	0.0903	-0.0051	-0.1073	1	-	-	-
LogImport	-0.2745	-0.0883	0.0355	-0.0871	1	-	-
LogRD	**0.864**	0.7417	0.3039	-0.0058	-0.175	1	-
LogResearcher	0.4123	0.3267	0.6274	-0.1306	-0.0371	0.418	1

Appendix C. Variance Inflation Factor

Model 1	
GL_HT	1.18
GL_MT	1.23
GL_LT	1.18
Fdi	1.11
LogImport	1.3
LogRD	1.15
LogResearcher	1.07
Mean VIF	1.17

Model 2	
VERTHQ_HT	1.82
VERTHQ_MT	1.6
VERTHQ_LT	1
Fdi	1.05
LogImport	1.1
LogResearcher	1.27
Mean VIF	1.31